Detecting Water Quality Changes by Landsat 8 OLI
: A Case Study of Taedong River, North Korea

Institute of Information & Communications Technology Planning & Evaluation

KYUNG HEE UNIVERSITY

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AMERICA VIEW — GEORGIA VIEW

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1. Introduction

The land cover of North Korea has experienced significant human impacts over the last several decades. Agricultural lands were increased for obtaining food, trees were lost for firewood, and built-up areas, particularly in the Pyongyang area, were expanded. Consequently, the hydrology in North Korea has been affected by the heavily deforested land cover.

Without enough literature about how such land cover affects water quality in a river, this study analyzed the Taedong River and its water basin as a case study area, because the river is the major water source for the people in the Capitol of North Korea, i.e., Pyongyang, and most of its watershed is covered by some typical land cover types found in North Korea such as agricultural wet and dry fields, heavily deforested lands, built-up areas, and forests.

Using satellite imagery and DEM in the Google Earth Engine (GEE), this study aims at how North Korea's land cover affects water quality, how water quality changes temporarily, whether water qualities are different geographically along the river, and how water qualities are detected by multiband satellite imagery. As an indicator of water quality, we used the tasseled-cap brightness index (TC-B) and spectral reflectance.

2. Data and Methodology

A. Data

1) Google Earth Engine (GEE)
   a) **USGS Landsat 8 OLI L2_C2, Tier 1**, 2014 – 2021, March – November, WRS path 117 & row 33, cloud cover less than 10% & no ice, 35 scenes
   b) **NASA Global 30m DEM**
2) Ministry of Environment, ROK
   a) **North Korea Land Cover Map**, 30m, 2019

Land Cover	Biryu	Hwangju	Sunhwa	Jaeryeong	Hapjang	Potong
Built-up	1.78	1.79	9.27	1.79	17.73	15.73
Agriculture	21.1	41.5	72.62	58.98	30.3	49.17
Forest	74.24	53.03	15.25	33.92	47.87	31.97
Grass	0.12	0.01	-	-	1.51	0.01
Wetland	-	0.14	0.02	0.3	0.4	0.09
Barren	2.3	2.13	1.04	2.4	0.27	0.75
Water	0.46	1.4	1.81	2.61	1.91	2.29

Table 1. The percent (%) land cover of sample tributary watersheds

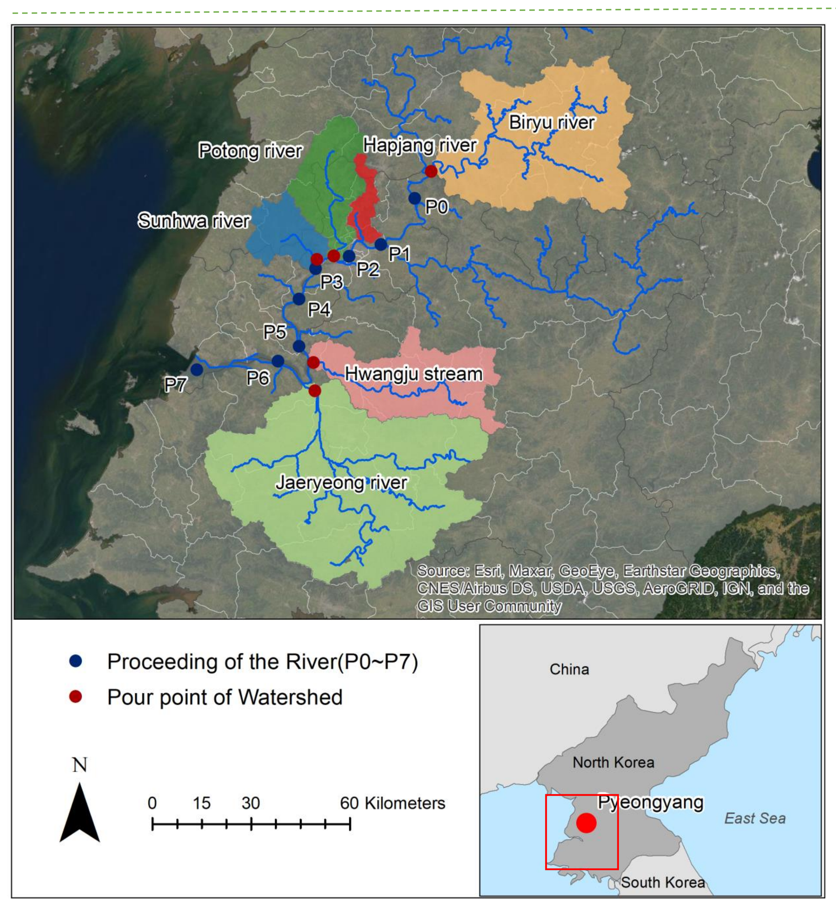

Figure 1. Taedong River and the watersheds sampled

Tributary	Latitude	Longitude
Biryu	39.24102	126.04023
Hwangju	38.71280	125.63619
Sunhwa	38.99600	125.64195
Jaeryeong	38.63568	125.64176
Hapjang	39.05523	125.79830
Potong	39.00556	125.70177

Table 2. The pour point locations of tributaries

Sample Point	Latitude	Longitude
P0 (Upstream)	39.16637	125.98336
P1	39.03886	125.86521
P2	39.00567	39.00567
P3	38.97054	125.63792
P4	38.88619	125.58142
P5	38.75687	125.58378
P6	38.71496	125.51168
P7 (Downstream)	38.68787	125.22791

Table 3. The sample point locations along Taedong River

B. Methodology

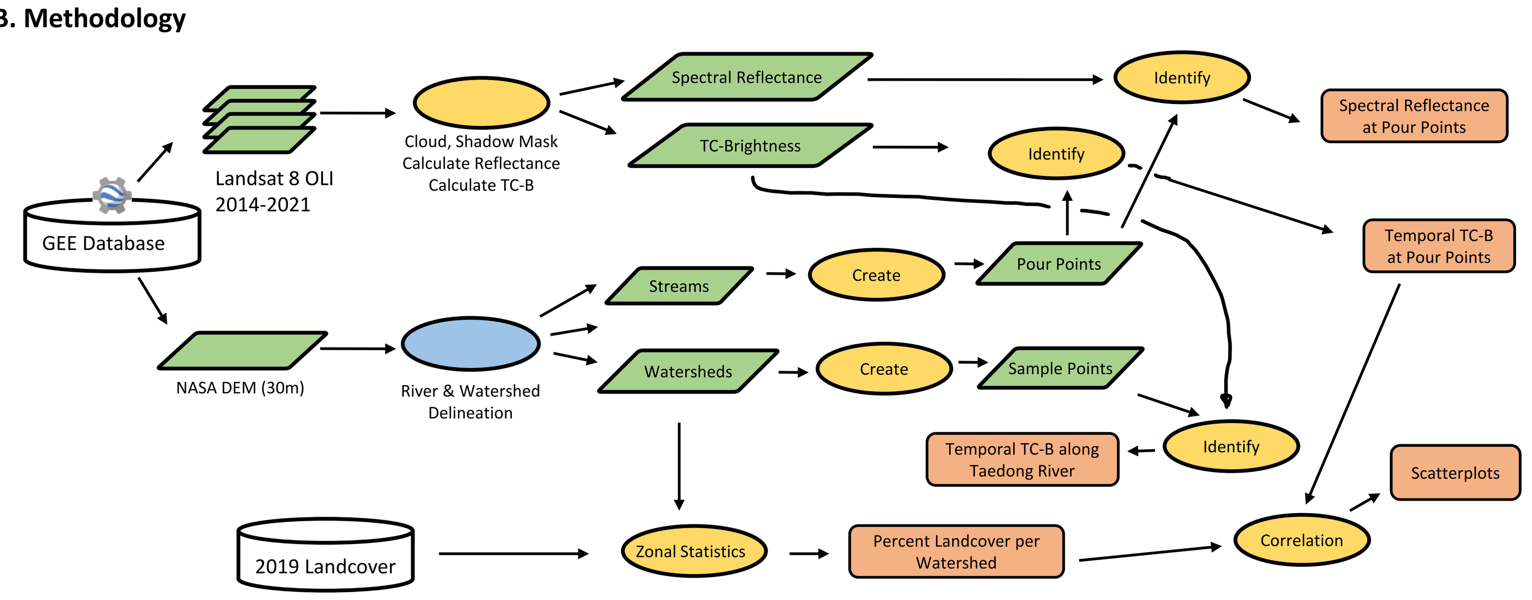

Figure 2. Research Flow Chart

TC-Brightness (TC-B) = 0.3029 x Blue + 0.2786 x Green + 0.4733 x Red + 0.5599 x NIR + 0.508 x SWIR1 + 0.1872 x SWIR2
(Baig et al., 2014)

3. Results

A. Monthly Difference

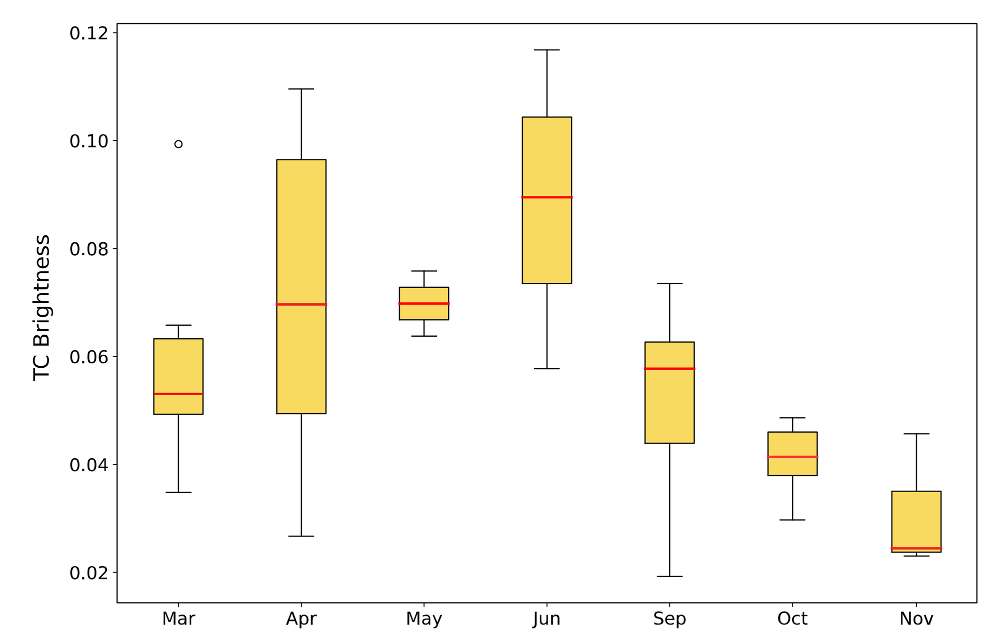

Figure 3. Monthly difference of Tasseled-cap Brightness at P2 in Taedong River

The monthly brightness values were identified at P2, located in the city of Pyongyang. The TC-B value gradually increases till June and then drops sharply in the fall. The high turbidity in spring and summer seems to be caused by active agricultural activities. The highest value of turbidity in June, particularly, appears to be due to the frequent early-spring droughts, agricultural water uses, and soil erosion by the squall.

B. Geographic TC-B Difference along Taedong River

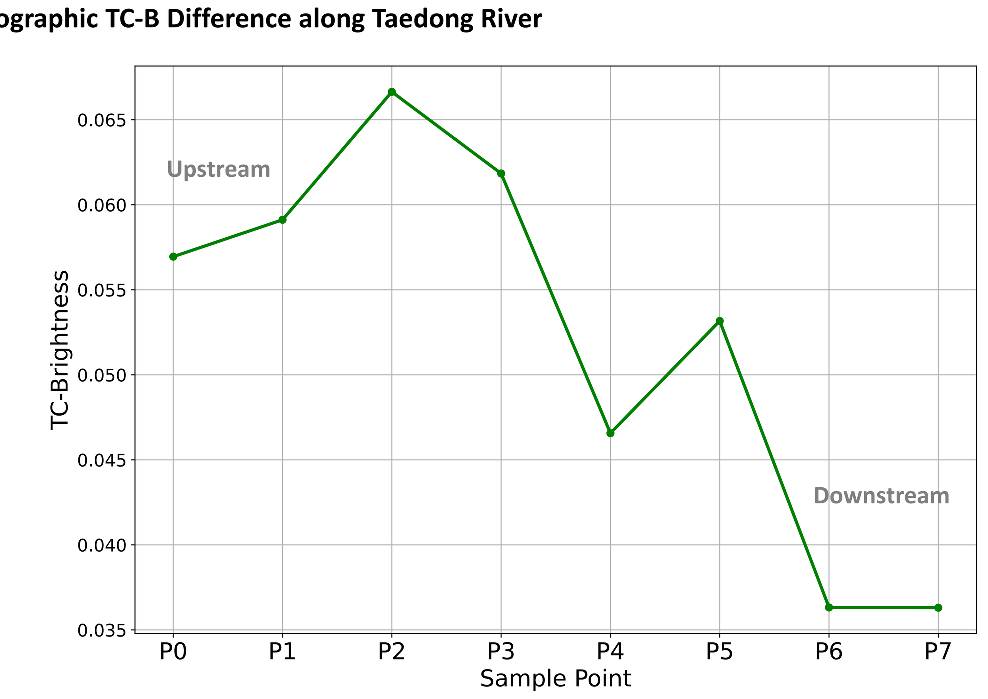

Figure 4. Mean TC-B at the sample points P0 to P7

Figure 4 shows the median TC-B values at P0 – P7. P0 and P1 are located at upstream above the Mirin Lock and Dam. P2 and P3 are located near the Pyongyang urban area. P4 and P5 are located right below the Pyongyang urban area. P6 and P7 are located at downstream right above the West Sea barrage.

The highest TC-B occurs where the Taedong River passes the Pyongyang city area, i.e., at P2. It appears that farming, open lands, and relatively larger impervious surfaces contribute to the turbidity of the Taedong River.

Interestingly, the TC-B values at upstream are much higher than those at downstream. This result is opposite to the findings from the case of the Han River in Seoul, South Korea (Seong et al., 2017) where downstream is more turbid than upstream. In the Taedong River watershed, it appears that heavy sediment loads from soil erosion reach their peak at where farming activities, particularly dry-fields, are frequent, and then they settle down as water flows downstream. It also implies that the low brightness values at the downstream area are partly attributed to paddy rice farming.

C. Band Reflectance Characteristics

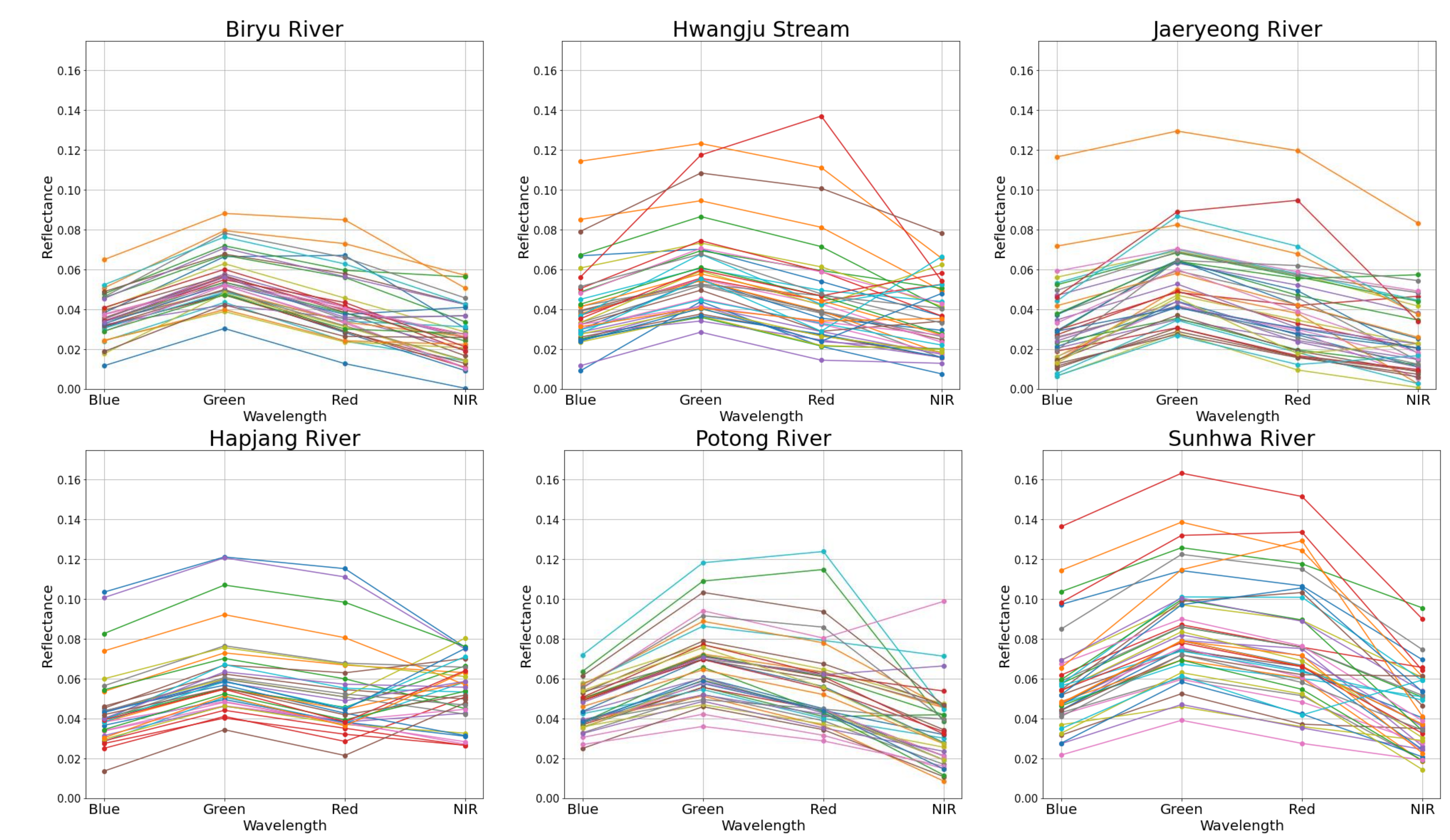

Figure 4. Spectral reflectance profiles at the pour points of tributaries that were identified from the 39 Landsat 8 images from 2014 to 2021

The Biryu River shows a relatively clustered pattern of the 35 spectral profiles with a reflectance range of about 0.06, while the spectral profiles in the Sunhwa River range about 0.12. The larger range indicates more dramatic changes of water colors, and higher reflectance values indicate more turbidity. In the case of the Biryu River, about 74.2% of the watershed is forest which is the highest among watersheds, so that the least soil loss is expected consequently contributing to constantly lower turbidity levels. On the contrary, the Sunhwa river watershed has the lowest forest percent compared with other watersheds and has a high proportion of agricultural land and urban areas.

D. Relationship between Land Cover and Water Quality

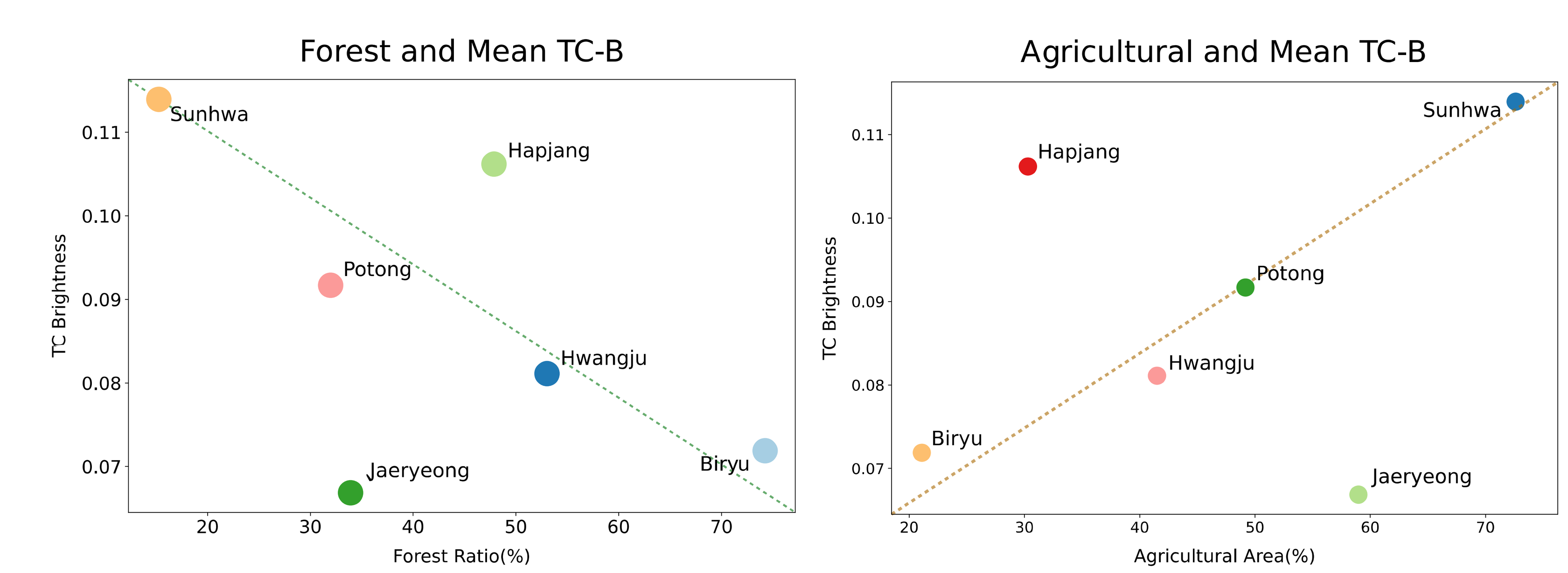

Figure 5. Scatterplots between land cover and TC-B at six watersheds

The scatterplots show decreasing TC-B values as the forest ratio increases. Also, TC-B increases as agricultural land cover increases. Two outliers appear in the diagrams – Hapjang River and Jaeryeong River. In the case of the Hapjang River, its watershed has a large proportion of forests, but also a large proportion of urban and built-up areas. It appears that the high proportion of impervious surfaces contributes to the high TC-B. In the case of the Jaeryeong River watershed, a large proportion is farm fields, particularly wet rice fields on gentle slope terrains. Considering that water is better managed on rice paddies, the large portion of rice paddies in the Jaeryeong River watershed seems to decrease water turbidity significantly.

4. Summary

The Taedong River originates in the mountains of North Korea and flows through Pyongyang. This water resource is closely related to North Koreans' lives. The Taedong River watershed has experienced dramatic land cover change over the last decades. This research studied the water quality of the Taedong River using satellite imagery and DEM available at GEE.

A total of 35 Landsat 8 scenes were used to calculate spectral reflectance and TC-B, and tributaries and watersheds were delineated by using NASA DEM in ArcGIS Pro. The 2019 North Korea land cover map was used to quantize land cover proportions in sample watersheds.

Results show that the Taedong River is more turbid in spring and summer. The spatial variance of water quality along the river was different from the case of the Han River in Seoul, South Korea. The TC-B values at P2 and P3, which are located midstream and near Pyongyang, were highest. Band reflectance values at downstream were lower than upstream. It shows that the Taedong River's downstream is clearer than upstream.

The Biryu River showed relatively lower spectral reflectance profiles, and the Sunhwa River showed relatively higher spectral reflectance profiles during the study period. The other tributaries showed about 3 to 5 days with high reflectance profiles.

As the forest ratio increases, the TC-B values tend to decrease. On the contrary, the agricultural fields tend to increase TC-B values. Also, the urban and built-up areas increase water turbidity, while the rice paddies decrease water turbidity.

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References

Chen, C., Fu, J., Zhang, S. and Zhao, X., 2019. Coastline information extraction based on the tasseled cap transformation of Landsat-8 OLI images. Estuarine, Coastal and Shelf Science, 217, pp.281-291.

Crist, E.P. and Cicone, R.C., 1984. A physically-based transformation of Thematic Mapper data---The TM Tasseled Cap. IEEE Transactions on Geoscience and Remote sensing, (3), pp.256-263.

Mertes, L.A., Smith, M.O. and Adams, J.B., 1993. Estimating suspended sediment concentrations in surface waters of the Amazon River wetlands from Landsat images. Remote Sensing of Environment, 43(3), pp.281-301.

Seong, J.C., Hwang, C.S., Gibbs, R., Roh, K., Mehdi, M.R., Oh, C. and Jeong, J.J., 2017. Landsat big data analysis for detecting long-term water quality changes: a case study in the Han River, South Korea. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 4, p.83.

Wang, J.J., Lu, X.X., Liew, S.C. and Zhou, Y., 2009. Retrieval of suspended sediment concentrations in large turbid rivers using Landsat ETM+: an example from the Yangtze River, China. Earth Surface Processes and Landforms, 34(8), pp.1082-1092.

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